Musculoskeletal Disorders and their Relationship to Vibration Exposure in Forklift Operators in a Paper Company, 2025

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Abstract

Introduction: Forklift operators are exposed to whole-body vibration (WBV) and biomechanical loads that could increase musculoskeletal disorders (MSDs).

Objective: To analyze the association between musculoskeletal discomfort (CMDQ) and normalized daily exposure A(8) to WBV in forklift operators in a paper industry in Cotopaxi, Ecuador.

Methods: Quantitative, observational, descriptive-correlational, cross-sectional study with 54 male operators. WBV was measured with a triaxial accelerometer in the seat following ISO 2631-1:1997; A(8) was calculated. Discomfort was assessed with the Cornell Musculoskeletal Discomfort Questionnaire (CMDQ). Descriptive statistics were applied; Spearman for correlations; Kruskal–Wallis and ANOVA with Bonferroni for comparisons; chi-square/Fisher and binary logistic regression by anatomical regions ($\alpha = 0.05$).

Results: The most affected regions were neck (68.5%), lower back (66.7%) and shoulders (59.3%). In exposure A(8), 38.9 % were above the limit, 25.9 % in the action zone and 35.2 % in low risk. The total CMDQ score did not correlate with A(8) ($\rho = -0.100$; $p = 0.473$), but it did correlate with age ($\rho = 0.451$; $p = 0.001$) and years of service ($\rho = 0.360$; $p = 0.007$). In the analysis by regions, only hips showed an association with WBV (OR = 4.453; 95% CI: 1.228–16.144; p =

0.016). Those over 40 years of age had higher CMDQ scores compared to 18–29 years ($p < 0.001$) and 30–40 years ($p = 0.006$).

Conclusions: There is a high prevalence of MSDs, especially in the neck, lower back and shoulders. Although A(8) was not associated with the global CMDC, WBV exposure increased the likelihood of hip discomfort and discomfort increased with age and age. Preventive measures (active breaks, vibration maintenance/isolation and exposure management) are required, prioritizing older workers/seniority.

Keywords*:* Musculoskeletal Disorders; Whole Body Vibrations; Occupational Exposure; Ergonomics; Pain of the Lumbar Region; Forklift Operators.

1. Introduction

Musculoskeletal disorders (MSDs) have a global prevalence, affecting over 1.7 billion individuals worldwide. These disorders are the leading cause of disability, as reported by the Global Burden of Disease (GBD 2019). Low back pain is the most prevalent form, accounting for 570 million cases. While these conditions are more prevalent among older adults, they can also manifest in younger individuals, potentially impacting their work capacity. The International Labor Organization (ILO) has issued a report that highlights the prevalence of occupational diseases, which are responsible for approximately two million deaths annually and contribute to losses amounting to 4% of global GDP. This predicament necessitates the fortification of preventive measures through the utilization of reliable data, the implementation of effective regulatory frameworks, and the promotion of social participation. The dearth of statistics in numerous nations impedes the implementation of effective preventive strategies (ILO, 2021; WHO, 2022).

It is estimated that 1.710 billion people worldwide are affected by some form of TME, which can impact muscles, nerves, tendons, and intervertebral discs. The most prevalent symptoms include lumbar pain, neck pain, and disc injuries (Ormaza et al., 2024). These conditions are primarily associated with biomechanical factors, such as awkward postures and prolonged exposure to mechanical vibrations (Sharma et al., 2025).

In this context, whole-body vibration (WBV) has been identified as a critical occupational hazard due to its cumulative effect on the spine (Macedo et al., 2022). Recent reviews have not yielded conclusive evidence of disc degeneration through imaging studies. However, in addition to previous research, they document a significant relationship between prolonged exposure to WBV and chronic low back pain, especially in professional drivers, including forklift operators (El Aarbaoui, Roff, & Krause, 2023). The combination of continuous vibrations and maintained postures is emerging as a determining factor in the development of TME in the lumbar region (Chen et al., 2024).

In the paper industry, forklifts are indispensable tools for the efficient handling of loads in confined spaces, optimizing logistics processes, and reducing the physical exertion of the worker (Rabal Pelay, 2021). However, their continuous use exposes operators to simultaneous ergonomic risks, such as repetitive movements, sudden accelerations, and sustained postures. These factors, in combination with the vibratory action, generate a high biomechanical load on the spine (El Aarbaoui, Roff, & Krause, 2023).

In Ecuador, a study conducted in Ambato revealed that vibration levels in heavy machinery exceeded the permissible limits established in ISO 5349-2:2001 and NTP 839, with values reaching up to 6.81 m/s^2. The measurements indicated a high vibratory load on the back-chest and shoulder-shoulder axes, which poses a significant risk to occupational health (Paredes Robalino et al., 2025). While these studies are relevant, a gap persists in the specific analysis of forklift operators, especially in sectors such as paper, where particular working conditions could intensify risks.

In the regulatory domain, Spain has instituted specific regulations aimed at controlling exposure to mechanical vibrations. According to Royal Decree 1311/2005, the A(8) value is defined as a standard daily exposure to an eight-hour workday. The risk is classified into three levels: acceptable (below the action value, < 0.5 m/s^2), intermediate (between the action value and the limit, ≤ 0.5 m/s^2 and ≤ 1.15 m/s^2, respectively), and critical (above the limit, ≥ 1.15 m/s^2, requiring immediate intervention). This regulatory framework differentiates between whole-body vibrations and those that affect the hand-arm system, thereby providing a comprehensive technical framework for occupational risk management (de la Hoz-Torres et al., 2022).

A study administered to 47 forklift operators using the Cornell Musculoskeletal Discomfort Questionnaire (CMDQ) revealed a high prevalence of lumbar (65.45%) and cervical (13.03%) discomfort, with moderate or severe intensity (de la Hoz-Torres et al., 2022). These discomforts have been found to be closely related to WBV exposure, which can be increased by factors such as uneven surfaces, inadequate speed, or deteriorated seats (Bhuiyan et al., 2022).

In order to mitigate the aforementioned risk, technical strategies have been proposed. One such strategy is the use of air suspension seats, which have been shown to reduce average acceleration by up to 39% under normal conditions and by an additional 29% on uneven terrain (ISO 2631-1:1997). Vibrations, defined as continuous oscillations transmitted to the body from an external source, have been shown to have a detrimental effect on health when exposure is prolonged (Robalino et al., 2025). In forklift operators, this condition can trigger or exacerbate

MSDs depending on the intensity, duration, and frequency of the stimulus (Ithnin et al., 2024; Santos et al., 2024).

In Ecuador, the extant literature on the prevalence and impact of MSDs in work settings remains limited (Moncayo, 2025). However, Executive Decree 255 – Annex 3 – Art. The fifth standard delineates a technical protocol for the mitigation of risks stemming from exposure to vibrations. This protocol stipulates criteria, control hierarchies, limit values, and methodologies, in accordance with the provisions set forth in ISO 2631-1. As posited by Bhuiyan et al. (2022), an action level of 0.5 m/s^2 and an exposure limit value of 1.15 m/s^2 are established for an eight-hour workday (A(8)).

The regulations stipulate the implementation of a hierarchical control framework, which encompasses the elimination or replacement of equipment, the implementation of engineering measures such as active suspension seats and insulated cabins, the introduction of administrative controls including task rotation and reduction of exposure time, and the utilization of anti-vibration devices when other measures are not viable (NIOSH, n.d.; Zielinski Nguyen Ajslev et al., 2024).

Assessments should be carried out using recognized methodologies, such as ISO 2631-1:1997, to identify risk conditions and take corrective action. Chronic exposure to WBV has been associated with a variety of health concerns, including low back pain, disc abnormalities, musculoskeletal fatigue, and impaired postural balance. This association has primarily been observed among mobile machinery operators (Barrie et al., 2025; Li et al., 2024; Podlaha et al., 2023).

Its effective implementation has been demonstrated to reduce various health-related issues, absenteeism, and financial expenditures. Furthermore, it serves to reinforce the employer's legal responsibility and integrates risk management into the broader business strategy. This necessitates internal audits, monitoring, technical measures, and continuous training, thereby cultivating an evidence-based preventive culture (Chuang et al., 2021).

In this context, the present study aims to analyze the association between musculoskeletal discomfort, measured with the CMDQ (Cornell Musculoskeletal Discomfort Questionnaire), and exposure to whole-body vibrations in forklift operators in a paper industry in Cotopaxi, Ecuador. The objective of the present study is to furnish empirical evidence to inform the development of preventive interventions in the domains of hygiene, ergonomics, and occupational health.

2. Materials and methods

A quantitative, observational, descriptive, and correlational study was conducted using a cross-sectional design. The objective of the study was to analyze the association between musculoskeletal discomfort and exposure to whole-body mechanical vibrations (WBV) in forklift operators. The population under study consisted of operators of a paper industry located in Cotopaxi, Ecuador. The sample included 54 male participants who were selected by non-probability convenience sampling.

The inclusion criteria stipulated that workers must have a minimum of one year of continuous experience in the position, with the exclusion of those with a recent history of trauma or non-work-related musculoskeletal diseases. All participants provided written informed consent in accordance with the ethical principles that govern research involving human subjects. A triaxial accelerometer (model APT2069D, OneProd® brand), calibrated by ACOEM France SAS, was utilized to assess WBV. The sensor was positioned on the surface of the forklift seat, in direct contact with the operator, in accordance with ISO 2631-1:1997. The acceleration data were recorded in three dimensions (X, Y, Z), with the vertical axis (Z) considered the most representative of the exhibition.

The search was conducted under real operating conditions, in various areas of the industrial site, on asphalt surfaces, cobblestones, compacted earth, and ramps. For each operator, a unique value of average daily exposure A(8) was calculated, representative of their usual routine. The Cornell Musculoskeletal Discomfort Questionnaire (CMDQ), a tool that has been validated in the context of ergonomic studies, was employed to identify musculoskeletal symptoms. The instrument under consideration is designed to evaluate three aspects of discomfort: its frequency, severity, and the extent to which it interferes with professional activities. It assesses these aspects in nine distinct body areas, including the neck, shoulders, elbows, wrists and hands, upper and lower back, hips, knees, ankles, and feet.

The participants completed the questionnaire individually, with the guidance of the research team during the day. The statistical processing was executed with IBM SPSS Statistics v25. A series of descriptive analyses were applied to characterize the sociodemographic variables, CMDQ scores, and levels of exposure to WBV. These analyses included frequencies, percentages, means, and standard deviations. To quantify the intensity of discomfort, a scale weighted by anatomical region was used, using the product of frequency × severity × interference. This allowed the identification of areas with the highest symptomatic burden (Çakıt, 2019).

The normality of the data was verified with the Kolmogorov-Smirnov and Shapiro-Wilk tests, determining the necessity of non-parametric tests. In order to ascertain the correlation between the total score on the CMDQ and the variables of age, length of service, and exposure A(8), the researchers employed the use of Spearman's correlation coefficient.

The differences in CMDQ according to the level of exposure to WBV (low risk, zone of action, and over limit) were assessed using the Kruskal-Wallis test. A one-factor analysis of variance (ANOVA) was subsequently conducted, followed by a Bonferroni post hoc test, to explore differences in musculoskeletal discomfort between age groups.

To ascertain the correlation between the occurrence of MSDs, categorized by anatomical region (spine, upper and lower limbs), and WBV exposure levels, the Chi-square test and Fisher's exact test were employed. A binary logistic regression model was subsequently constructed for each anatomical region, with the objective of estimating the effect of WBV exposure on the probability of presenting musculoskeletal discomfort. This estimation was expressed as odds ratio (OR) with 95% confidence intervals. The significance level was considered to be $p < 0.05$.

3. Results

The sample consisted of 54 participants, all of whom were male (100%). Regarding age demographics, the data revealed that 68.5% of the subjects fell within the 30-40 age range, 18.5% were between 18 and 29 years of age, and 13.0% were over 40 years of age. Regarding years of service, the data reveal that 55.6% of the sample had between six and 10 years of seniority, 25.9% had between one and five years of seniority, 11.1% had between 11 and 15 years of seniority, and 7.4% had more than 15 years of seniority (Table 1).

Table 1

Sociodemographic characteristics.

Sex	F	%
Man	54	100
Woman	-	-
Age		
18 to 29 years old	10	18.5

30 to 40 years old	37	68.5
More than 40 years	7	13.0
Years of Service		
1 to 5 years	14	25.9
6 to 10 years	30	55.6
11 to 15 years old	6	11.1
more than 15 years	4	7.4
Total	54	100.0

Note: n=54. Source: Database

The results of the Cornell Musculoskeletal Discomfort Questionnaire (CMDQ) identified the most affected body areas in forklift operators. The highest proportions of discomfort were reported in the neck (68.5%), lower back (66.7%), and shoulders (59.3%), while the lowest were recorded in elbows (5.6%) and ankles/feet (5.6%). Regarding the average scores, the lower back presented the highest mean (10.70; SD = 11.31), followed by the neck (9.74; SD = 8.48) and upper back (7.28; SD = 9.16). The areas with the lowest scores were ankles/feet (1.07; SD = 0.33), elbows (1.39; SD = 2.59) and wrists/hands (3.33; SD = 4.48) (Table 2).

Table 2

Percentage of musculoskeletal discomfort and average scores by body region according to the CMDQ.

Body Region	% with discomfort	Mean (CMDQ score)	OF
Neck	68.5	9.74	8.48
Shoulders	59.3	6.41	5.86
Upper back	50.0	7.28	9.16
Lower back	66.7	10.70	11.31
Wrists and hands	33.3	3.33	4.48
Elbows	5.6	1.39	2.59
Hips	42.6	6.19	8.38
Knees	27.8	4.26	8.08
Ankles and feet	5.6	1.07	0.33

Note. n=54. Source: Database

Based on equivalent acceleration values A (8), 38.9% of forklift operators (n = 21) are at an exposure level above the recommended limit. 25.9% (n = 14) are located in the so-called action zone, while 35.2% (n = 19) have an exposure level classified as low risk (Table 3).

Table 3

Whole-body vibration exposure levels in forklift operators according to A values (8).

Risk level	f	%
Low risk	19	35,2
Action Zone	14	25,9
Above the limit	21	38,9

Note. n=54. Source: Database

Regarding the association between musculoskeletal disorders measured by the CMDQ, exposure to vibrations A (8) and sociodemographic variables, the normality of the variables was evaluated using the Kolmogorov-Smirnov and Shapiro-Wilk tests. The total score of the CMDQ showed a non-normal distribution according to the Shapiro-Wilk test (p = 0.007), as did exposure to whole-body vibrations (A(8)), whose p-value was 0.000. Since both variables did not follow a normal distribution, Spearman's nonparametric correlation was applied. The results showed a moderate positive correlation between age and total CMDQ score (ρ = 0.451; p = 0.001), as well as between years of service and total CMDQ score (ρ = 0.360; p = 0.007). No significant correlation was observed between exposure A (8) and total CMDQ score (ρ = –0.100; p = 0.473), (Table 4).

Table 4

Association between musculoskeletal disorders measured by the CMDQ, exposure to vibrations A (8) and sociodemographic variables.

			Age	Years of Service	CMDQ Total Score	Exposure A (8)
Spearman's Rho	Age	*ρ* (rho)	1	,839**	,451**	-0,03
		P	.	0	0,001	0,828
		N	54	54	54	54
	Years of Service	*ρ* (rho)	,839**	1	,360**	-0,005

	P	0	.	0,007	0,971
	N	54	54	54	54
CMDQ Total Score	ρ (rho)	,451**	,360**	1	-0,1
	P	0,001	0,007	.	0,473
	N	54	54	54	54
Exposure A (8)	ρ (rho)	-0,03	-0,005	-0,1	1
	P	0,828	0,971	0,473	.
	N	54	54	54	54

Note. **ρ** = Spearman's correlation coefficient. **p** = bilateral significance value. **n** = 54. **The correlation is significant at the 0.01 level (bilateral).** Source: Database.

Additionally, in order to explore differences in the total score of the CMDQ according to age groups, an ANOVA test was performed followed by a post hoc analysis using the Bonferroni method. The results indicated statistically significant differences in the total score of musculoskeletal discomfort between the different age ranges. In particular, the group of participants over 40 years of age had significantly higher scores compared to the 18 to 29 years old (p = 0.000) and 30 to 40 years old (p = 0.006) groups. These findings complement the results obtained in Table 4, confirming that age is positively associated with higher levels of musculoskeletal discomfort (Table 5).

Table 5

Post hoc Bonferroni: Age vs. CMDQ Total Score

Dependent variable: CMDQ Total Score						
(I) Age	(J) Age	Half (I-J)	Standard Error	P value	95% confidence interval	
					Lower limit	Upper limit
18 to 29 years old	30 to 40 years old	-18,3216	8,52354	0,109	-39,4218	2,7785
	More than 40 years	-50,2714*	11,78549	0	-79,4466	-21,0963
30 to 40 years old	18 to 29 years old	18,3216	8,52354	0,109	-2,7785	39,4218

	More than 40 years	-31,9498*	9,85709	0,006	-56,3512	-7,5484
More than 40 years	18 to 29 years old	50,2714*	11,78549	0	21,0963	79,4466
	30 to 40 years old	31,9498*	9,85709	0,006	7,5484	56,3512

Note. Dependent variable: CMDQ total score. It is based on observed averages. The error term is the square mean (Error) = 571.932. $p < 0.05$ indicates a significant difference. $n = 54$. Source: Database.

The Chi-square test was thus employed to ascertain the association between the presence of musculoskeletal disorders (MSDs) as indicated by the CMDQ questionnaire, grouped by anatomical region, and exposure to whole-body vibrations (WBV). In the upper limb region (shoulders, elbows, wrists, and hands), a marginally significant association was observed according to Pearson's Chi-square statistic ($\chi^2 = 3.620$; $p = 0.057$) and the unilateral value of Fisher's exact test ($p = 0.053$). These findings suggest a possible relationship between WBV exposure and the presence of TME in

The region under consideration is as follows: In contrast, no statistically significant associations were identified for the region of the spine (neck, upper and lower back) ($\chi^2 = 1.724$; $p = 0.189$) or for the lower limbs (hips, knees, ankles and feet) ($\chi^2 = 1.586$; $p = 0.208$). The findings of this study suggest that MSDs in these regions do not appear to be meaningfully associated with WBV exposure levels (Table 6).

Table 6

Analysis of the association between the presence of TME by anatomical regions and exposure to whole-body vibrations (WBV).

Anatomical region	**χ²**	**Gl**	**P value**	**p Fisher bilateral**	**p Fisher unilateral**
Spine (neck, upper and lower back)	1,724	1	0,189	0,544	0,264
Upper limbs (shoulders, elbows, wrists, and hands)	3,62	1	0,057	0,102	0,053

Lower limbs (hips, knees, ankles, and feet)	1,586	1	0,208	0,259	0,165

Note. n = 54. χ^2 = Chi-square; gl = degrees of freedom; p = level of significance; MSD = musculoskeletal disorders. Source: Database.

Finally, a binary logistic regression analysis was performed to evaluate the association between the presence of whole-body vibration (WBV) and musculoskeletal symptomatology in the nine anatomical zones. Among the nine models examined, only the hip model demonstrated a statistically significant association with WBV exposure ($\chi^2 = 5.851$, $p = 0.016$), with an Odds Ratio (OR) of 4.453 (95% CI: 1.228–16.144). This indicates that individuals exposed to WBV are 4.45 times more likely to report hip discomfort compared to those not exposed. Furthermore, the model accounted for between 10.3% (Cox and Snell R^2) and 13.8% (Nagelkerke R^2) of the variance and obtained an overall ranking percentage of 63.0%.

In contrast, for the other areas (neck, shoulders, upper back, lower back, elbows, wrists and hands, knees, ankles and feet), the models did not reach statistical significance ($p > 0.05$). As demonstrated in Table 7, although some regions, including the shoulders and upper back, exhibited moderate odds ratios (e.g., OR for shoulders = 0.378), the confidence intervals were extensive and crossed unity, indicating an absence of conclusive effect.

Table 7

Binary logistic regression results by anatomical zone in relation to exposure to whole-body vibration (WBV).

Anatomical Zone	**χ^2**	**p**	**R^2 Cox and Snell**	**R^2 Nagelkerke**	**OR (Exp(B))**	**95% CI (Lower)**	**95% CI (Superior)**	**Global Ranking (%)**
Neck	0	0,991	0	0	1,007	0,303	3,35	68,5
Shoulders	2,605	0,107	0,047	0,064	0,378	0,112	1,278	59,3
Upper back	2,048	0,152	0,037	0,050	0,438	0,139	1,378	59,3
Lower back	1,001	0,317	0,018	0,026	1,818	0,565	5,854	66,7
Elbows	1,304	0,254	0,024	0,068	0,250	0,021	2,956	94,4
Wrists and hands	1,001	0,317	0,018	0,026	0,550	0,171	1,771	66,7

Hips	5,851	0,016	0,103	0,138	4,453	1,228	16,144	63,0
Knees	0,031	0,859	0,001	0,001	1,120	0,319	3,937	72,2
Ankles and feet	1,304	0,254	0,024	0,068	0,250	0,021	2,956	94,4

Note. n = 54. χ^2 = Chi-square; OR = odds ratio; 95% CI = 95% confidence interval. Source: Database.

4. Discussion

The results indicate a high prevalence of musculoskeletal disorders (MSDs) in forklift operators, primarily in the lumbar, dorsal, gluteal, and cervical regions. This finding aligns with research that identifies low back pain as one of the primary causes of work disability in individuals exposed to whole-body vibration (WBV) (Bhuiyan et al., 2022; Erdem et al., 2020).

A significant association was observed between WBV levels and the presence of TME in various body segments, confirming that prolonged exposure, in conjunction with maintained postures, repetitive movements, and poor ergonomic conditions, generates a high biomechanical load and cumulative effects on the musculoskeletal system (Santos et al., 2024; Podlaha et al., 2023).

The risk analysis indicated that a significant proportion of workers are in the "area of action" or even above the permissible limit established by ISO 2631-1:1997 and Royal Decree 1311/2005. According to Directive 2002/44/EC, this scenario obliges the employer to apply immediate corrective measures, which reinforces the relevance of the proposal for active breaks as a preventive strategy.

A multitude of studies have demonstrated the efficacy of active breaks in reducing muscle fatigue, enhancing circulation, promoting joint mobility, and alleviating pain (Ithnin et al., 2024). This intervention aims to address the prevalence of MSDs and to enhance the quality of work life, increase productivity, and prevent absenteeism. Finally, although the Cornell Musculoskeletal Discomfort Questionnaire (CMDQ) was effective in identifying the areas most affected, it is recommended that objective evaluations, such as postural analysis, electromyography, or imaging studies, be included in future research. Additionally, longitudinal follow-up to measure the sustained impact of active breaks is advised.

5. Conclusions

The findings of the study indicate a high prevalence of musculoskeletal disorders (MSDs) among forklift operators in the paper industry, with a notable involvement of the neck, lower back, and shoulder regions. These discomforts, identified using the Cornell Musculoskeletal Discomfort Questionnaire (CMDQ), reflect a significant biomechanical load associated with the physical demands of the position, including sustained postures, repetitive maneuvers, and exposure to mechanical vibrations.

In relation to exposure to whole-body vibrations (WBV), it was determined that 38.9% of workers surpass the permissible limit value of daily exposure A(8), as stipulated by the ISO 2631-1:1997 standard. This outcome signifies a substantial ergonomic concern. Furthermore, 25.9% of the operators are engaged in the area of action, indicating that more than half of them are subject to levels that necessitate immediate corrective measures in accordance with the national and international legal framework.

The statistical analysis revealed that, although there is no significant correlation between the A(8) value and the total CMDQ score, a significant association was found between WBV exposure and discomfort in the hip region, with an Odds Ratio of 4.45. This suggests that operators who are exposed to vibration are more than four times more likely to experience discomfort in this anatomical area compared to those who are not exposed to the same extent.

Conversely, a positive correlation was identified between age and years of service with the level of musculoskeletal discomfort. This finding suggests that the accumulation of time in a given position, in conjunction with the prevailing biomechanical factors, may exacerbate symptoms over time. The relationship serves to underscore the significance of implementing preventive measures that are customized according to the worker's profile.

6. Recommendations

It is recommended that the program of active work breaks, which is currently underutilized, be reinstated with a minimum duration of 15 minutes per day during the workday. These breaks should include stretching and mobility exercises targeting the lumbar region, cervical spine, shoulders, and lower limbs. Operators who exhibit higher levels of discomfort, as indicated by the CMDQ, and those over 40 years of age, should be prioritized. This measure constitutes a low-cost and highly effective intervention in contexts with a high biomechanical load.

In addition, the implementation of brief and practical training sessions on a continuous and quarterly basis is recommended. These sessions should focus on postural hygiene, proper equipment usage, early detection of musculoskeletal discomfort, physical self-care strategies, and safe driving techniques on uneven surfaces. These measures are expected to encourage the adoption of preventive behaviors and facilitate the timely issuance of warnings concerning technical failures, which have been observed to increase exposure to vibrations.

From an ergonomic perspective, it is recommended to carry out periodic preventive maintenance of the forklift seats, which includes checking the condition of the padding, damping, and support points. This is particularly important when immediate replacement with models that feature air suspension may be economically unfeasible. As a cost-effective complementary measure, the utilization of ergonomic cushions with vibration absorption capacity is proposed to reduce direct exposure.

Finally, the necessity to maintain the periodic measurement of exposure to WBV by means of calibrated equipment is emphasized, integrating the results into an internal ergonomic risk surveillance system that allows for the recording of levels by worker and operational area. Furthermore, it is advisable to devise a strategy for the phased adaptation of traffic routes. This strategy should prioritize the leveling of uneven surfaces and the elimination of obstacles that contribute to the transmission of vibrations.

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